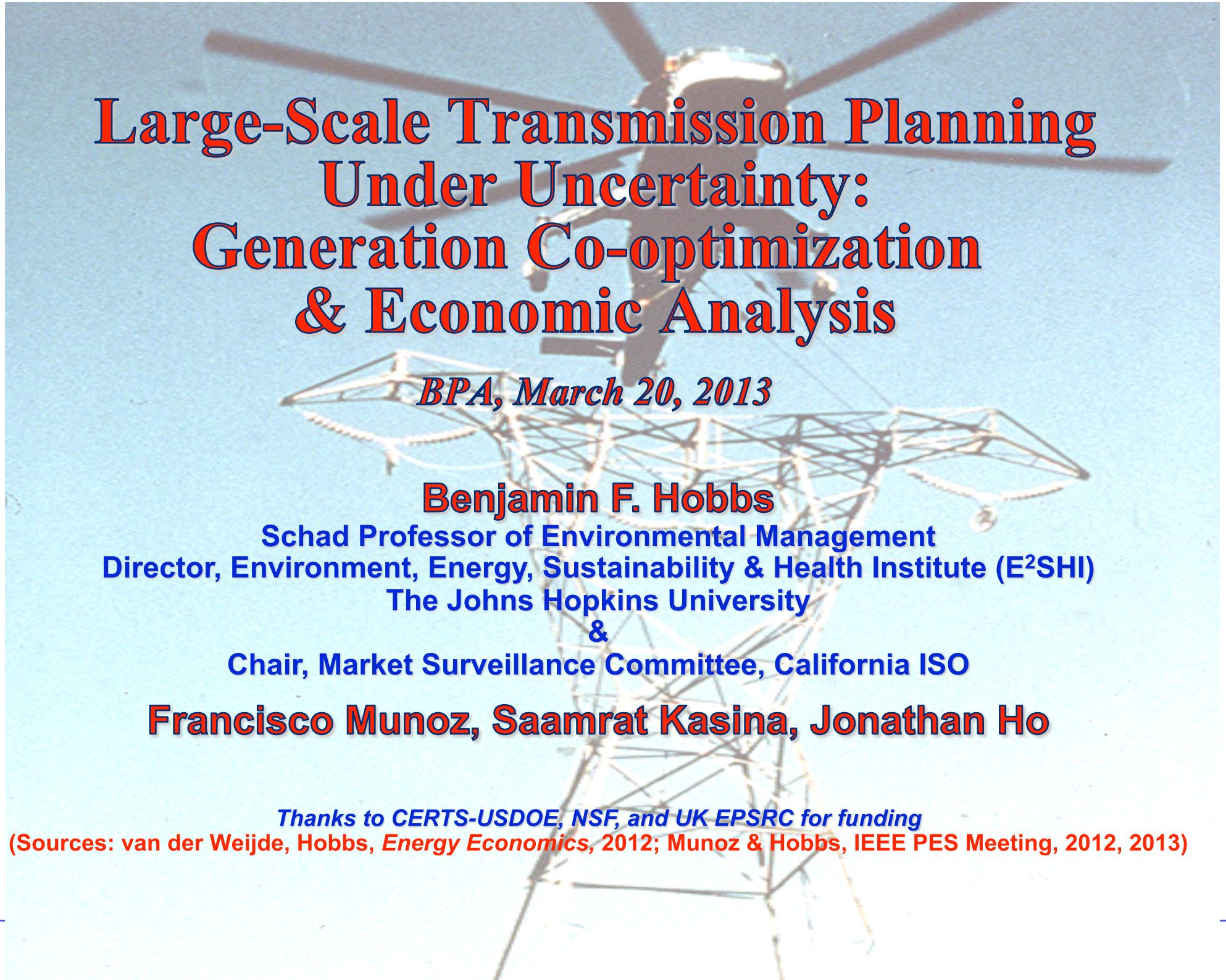

Large-Scale Transmission Planning Under Uncertainty: Generation Co-optimization & Economic Analysis

BPA, March 20, 2013

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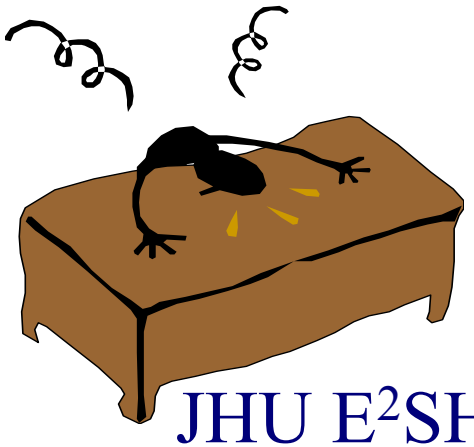
(Sources: van der Weijde, Hobbs, *Energy Economics,* 2012; Munoz & Hobbs, IEEE PES Meeting, 2012, 2013)

I. Challenge of Hyperuncertainty:
What's a Transmission Planner to do?

Dramatic changes coming!

- **Renewables**
  - How much?
  - Where?
  - What type?
- **Other generation**
  - Centralized?
  - Distributed?
- **Demand**
  - New uses? (EVs)
  - Controllability?
- **Policy**



The problem

Planning

- Decisions can be postponed: *multi-stage*
- Uncertainties & variability: *stochastic*
- Bilevel: *response of generators & consumers to grid decisions*

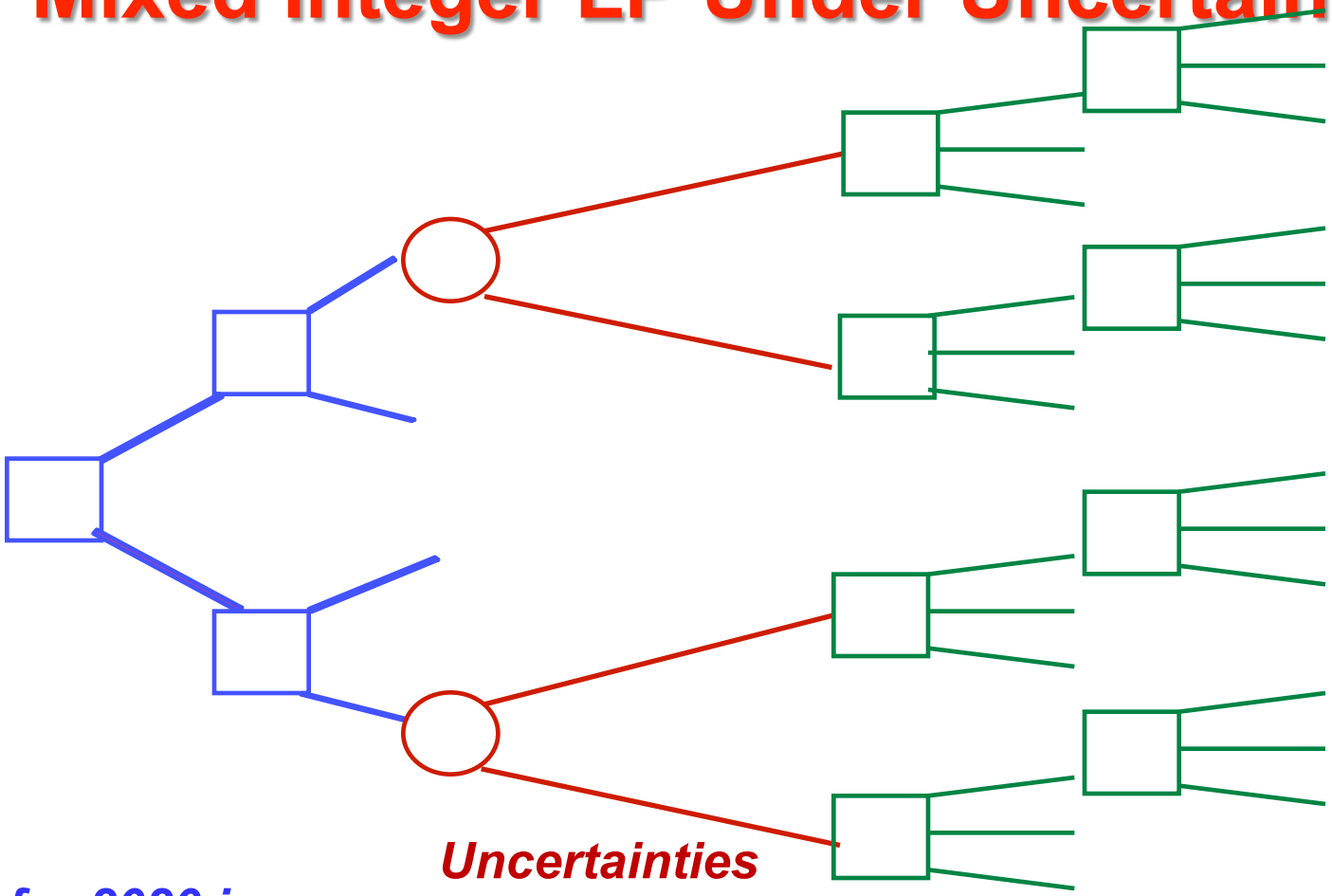
Important questions:

- Optimal strategy under uncertainty?
- Value of information & flexibility?
- Penalty for ignoring uncertainty?
- How gen investment responds to grid design?

Deterministic planning can't answer

- Stochastic multilevel can!
- Considers all scenarios simultaneously

Our Approach: Two-Stage Transmission Mixed Integer LP Under Uncertainty



Invest for 2020 in: transmission…generation

Uncertainties (policy, load, technology)

Invest for 2030 in: transmission…generation

Cf. NXT/NETPLAN (used by WECC): accounts for variability, *not* uncertainty

II. UK: Best near-term grid investments in face of 6 econ/policy scenarios

Onshore wind

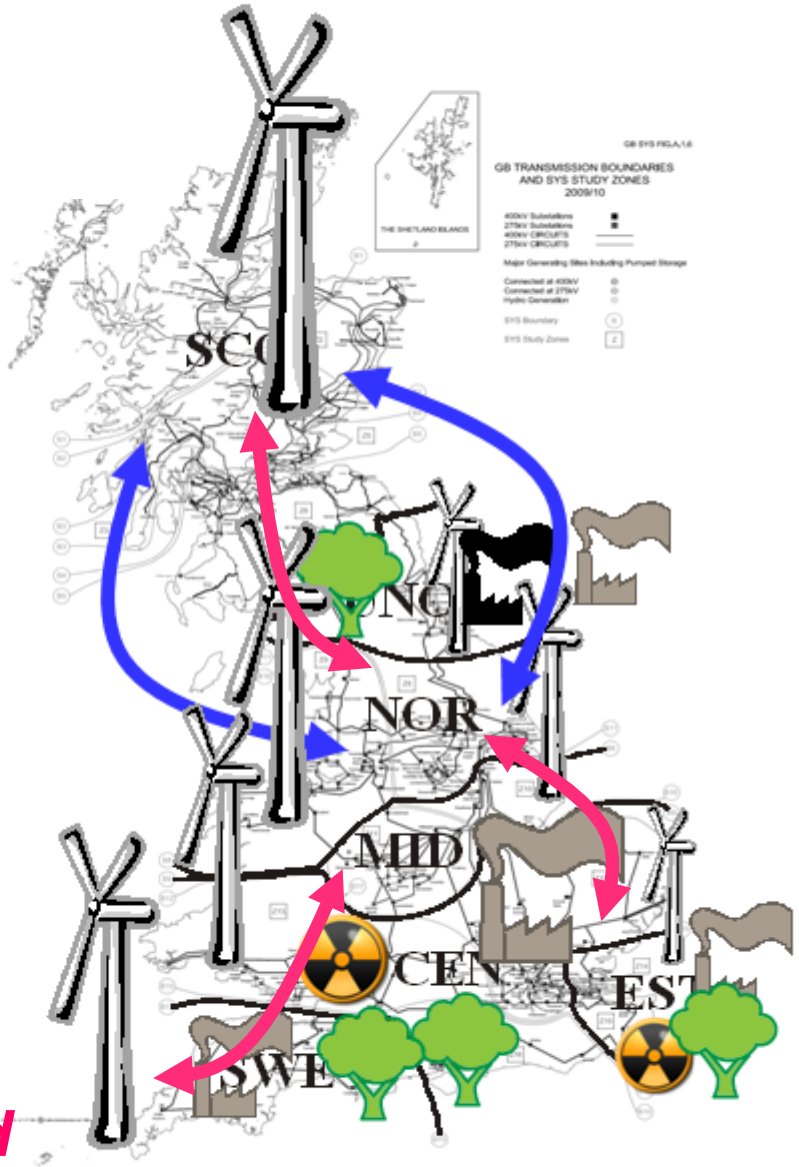
Offshore wind

Nuclear

Biomass

CCGT

OCGT



Uncertainty Means
Optimal to Delay 3 Lines
Recommended by National Grid

III. WECC 240-bus Test Case: MILP with ~10^6 -10^7 Variables

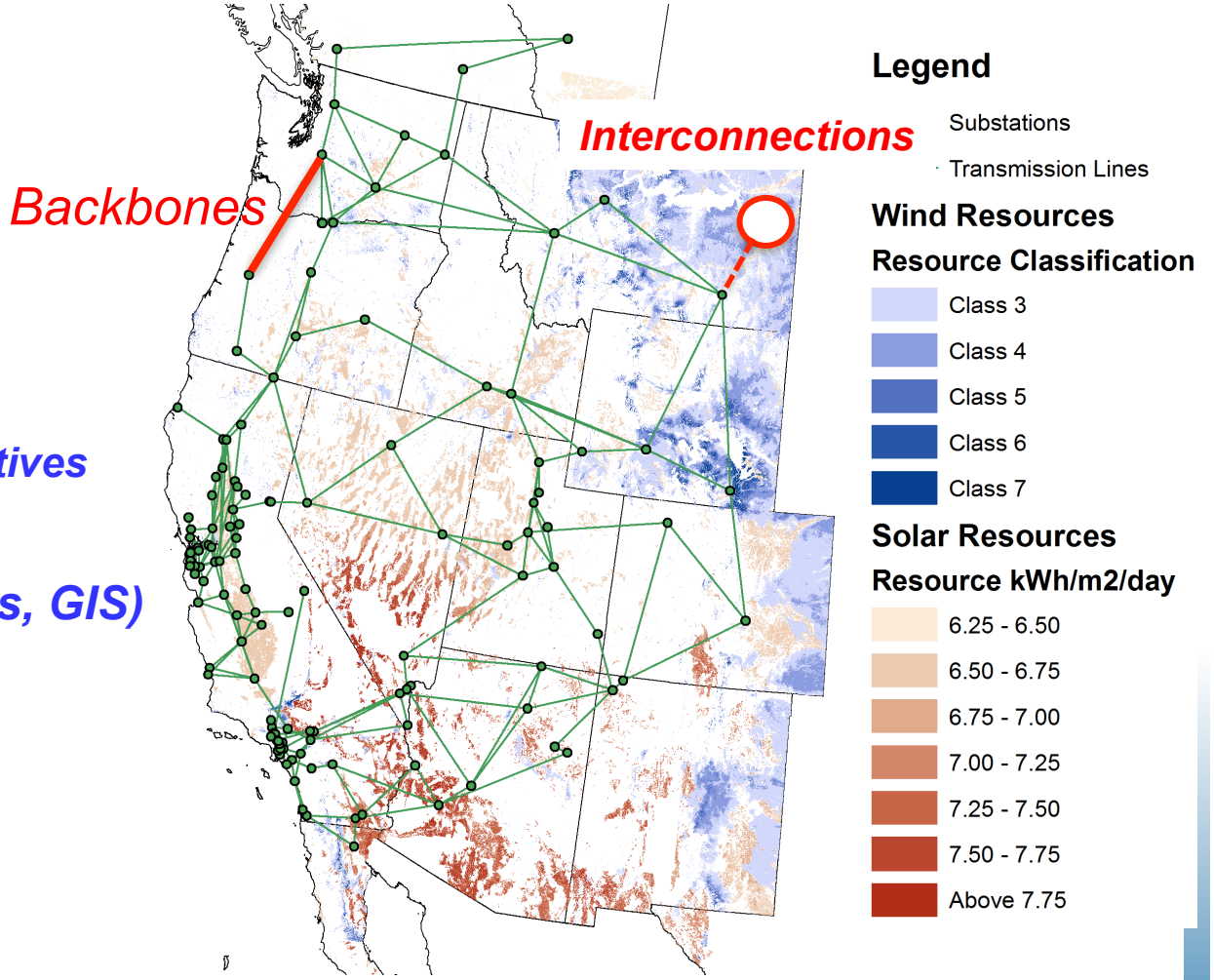
WECC 240-bus system:
(Price & Goodin, 2011)

140 Generators
448 Transmission elements

Candidate Transmission Alternatives

Renewables data (Time series, GIS)
(NREL, WREZ, RETI)

54 Wind profiles
29 Solar profiles



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Renewables data (Time series, GIS)
(NREL, WREZ, RETI)

Scenarios: WECC

Focus on environmental policy & fuel prices:

Differentiated State RPS

- *State RPS*
- *>75% from in-state resources*
- *Average fossil fuel prices*

33% WECC-wide RPS

- *33% WECC-wide RPS*
- *Efficient REC markets*
- *High fossil fuel prices*

Carbon Cap & Trade

- *17% below 2005 levels by 2020*
- *45% below 2005 levels by 2030*
- *Low fossil fuel prices*

Experiments:

- **Scenario Planning** (Deterministic)
- ***Stochastic Approach (All scenarios at once)***
- **Heuristics:**
  1. *Heuristic I: Build lines needed in all 3 scenarios*
  2. *Heuristic II: Build lines needed in "most" scenarios (≥2)*
  3. *Heuristic III: Build all lines built in any scenario*

"Least-regrets" or "Multi-Value Projects"

"Congestion-free"

Results: WECC

First-Stage Transmission Investments: Backbones

Approach	B19	B37	B56	B68	B72	B73	B74	B92	B95	B125	B133	B136	B137	B143	B151	B157	B168	B169	B201	B202	B218	B222	B237	B238
D-Carbon				1					1	1	1		1	2								2	1	2
D-33% WECC		1			1	1	2		1								1	1	1		1	1	2	
D-State RPS	2	1	1					2		2		1								1		1		2

Flexible plans are suboptimal in retrospect!

Approach	First-Stage Transmission Investments [$Bill]	Expected PW of G&T Costs [$ Bill]
D- Carbon Sce.	4.1	728.2
D-33% WECC S	15.4	653.6
D-State RPS Sce.	11.3	667.0
Heuristic I	0.4	951.4
Heuristic II	6.3	679.1
Heuristic III	24.2	644.5
Stochastic (All Scenarios)	14.8	636.2

Penalty for ignoring uncertainty:
= 46.7 $Bill.

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